Negotiating Future Foods: Cultural Practices and Nutritional Knowledge in NASA's Space Food Research Programs

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As NASA's astronauts embarked on the conquest of space in the 1960s a question arose: what should these heroes of high technology eat in space? Of course, earthly food was deemed not flight worthy. Therefore, NASA set itself to disrupting and reinventing the storage, preparation, and consumption of food for the Space Age. From the early 1960s onward, the Food & Nutrition research group that was located at NASA's Manned Space Center (MSC) in Houston started to research what food, cooking and eating meant and how it could optimize all three to make them suitable for space flight (1). In doing so NASA positioned itself not only as a government agency tasked with building rockets but also as a research agency where the scope of interest covered almost all aspects of human life, down to daily nutrition, in the hope of improving life on earth as well as in space. One goal, for example, was to combat world hunger with space food (NASA SP-202, pp. XIII). Another goal was to provide elderly people who were living alone with space food rations that were supposedly easy to cook and did not need refrigeration (2). The results of this ambitious redesign were delicacies such as bacon squares, strawberry cubes and dehydrated beef and gravy (3).

NASA's primary research aimed at establishing the physiological reactions of the human body to weightlessness by precisely measuring the astronauts' nutrient metabolism. Nevertheless, this research always took place in an area of conflict between different interest groups and actors. Engineers demanded light, safe and practically immaterial food in order not to exceed the technical capabilities of their spaceship designs. For the physiologists involved, the focus was on the exact control of all metabolic parameters, while astronauts were confronted with the question of whether they should see themselves as the lab rats of the experimental design or as co-investigators. Astronauts in particular disapproved of some of the specially designed foods: the fruitcake for example that NASA coated in starch and gelatin to avoid crumbling and that was advertised to housewives as a special treat for space crazy kids (Daily Telegram, 1968), drew ire from the astronauts of Apollo 8.

> *LMP:* Also, might tell Doc Frome that his toothpaste tastes pretty good. I don't know what kind of job it does on your teeth but it's nice for settling your stomach after dinner.
>
> *LMP:* Anything else, Frank?
>
> *CMP:* We used it for frosting on the fruitcake (4).

In other instances, Astronauts traded foods that they were expected to eat in a specific order to insure a traceable nutrient intake (5). Furthermore, they cursed the Food & Nutrition Branch's food scientist for providing faulty food packages that could not be opened, and forced ground control's experts in Houston into frantic discussions over the likelihood of food poisoning from a day-old opened can of tuna spread (6).

Research Outline: Material Culture of Food

Scholars of Food Studies have argued that food can be used as a marker for historical changes due to its embeddedness in a culinary system that conceptualizes food as a system of differential signs and accompanying rules of sign manipulation (Montanari, 2006, p.99; Douglas, 2017, p.95; Tolksdorf, 2017, p.127). This culinary system mirrors social, scientific and technological changes albeit in its own timeframe, sometimes directly, sometimes only belatedly (Kassung, 2020). From this point of view, the resistance that the astronauts showed to the dietary regime of the Food & Nutrition Branch could be interpreted as the effect of older and more stable culinary semantics, which were able to assert themselves against NASA's impulses for innovation (Cubasch, 2019; Levi, 2010). However, the cultural techniques that accompany food have to be studied alongside the culinary semantics of food, especially when quotidian materials like food become scientific objects in technoscientific contexts of government funded large-scale research and development (Klein and Spary, 2010; Geppert, 2012, p.220). Success and failure of intentionally induced changes in food habits like NASA's aimed for disruption and replacement of everyday foods with space food can only be fully understood when the material as well as the cultural basis of historical situations are studied (Bauer, 2006, pp.46–47). Broadly defined, cultural techniques are habituated manipulations of objects that rest on tacit and embodied knowledge rather than explicated and scientific knowledge (Krämer and Bredekamp,2009, p.18). Instead of written information, cultural techniques rely on a vast and differing array of media to be transmitted and to evolve (Kittler, 1986; Felsch, 2007, pp.13–16).

Against this theoretical background, we argue that NASA's nutritionists did three things during the 1960s and 1970s – the years of Gemini, Apollo and Skylab. Firstly, they tried to research what food was and how it interacted with the body of the astronauts. They concluded that food was the sum of its nutrients and that a precise control of nutrients had to be maintained at all times to sustain a safe environment for human residence in space. But this also meant controlling the astronaut's behavior to enforce adherence to research protocols. Secondly, they reframed and reorganized the cultural techniques of food preparation and developed new techniques of food engineering that transformed foods to space foods. Lastly, NASA reimagined what it meant to consume food, partly out of necessity in a zero-g environment, partly out of engineering ambitions. But these efforts were hampered by unwilling astronauts, spaceship engineers with different goals, and deficient food package designs. We trace the lines of these conflicts that emerged in NASA's food program and explore the history of a planned – and somewhat unsuccessful – disruption of western cuisine that was itself marred by internal disruptions. But while this paper shows how perspectives on food can differ in relation to each actor's position in research and development situations like NASA's space food program, it must not be forgotten that negotiations of food and its function always take place in a broader social context. Ross-Nazzal (2013), for example, has shown that the first female Shuttle astronauts had very different ideas of what comfort food was supposed to be, compared to their male colleagues. More thorough investigations are needed to illuminate how food research and development situations like this are shaped by societal dimensions of race, class and gender (7).

As Spiller (2004, p.741) has demonstrated for irradiated food technology, it is especially the linkage between culturally influential high technology – such as nuclear power and space technology – with quotidian food that not only fleshes out the different interpretations of the respective technology but also contemporary attitudes towards food (Bauer, 2006, pp.34, 314; Zachmann, 2011). Therefore, in studying the way NASA handled and reinvented food we can on the one hand contribute to a history of past futures of food, and on the other hand situate the history of spaceflight in broader contexts of contemporary culture (Belasco, 2006; Maher, 2017). To highlight the different perspectives on space food our research is based on archival sources from the MSC Houston to study the researcher's perspective but also the engineer's intentions and ambitions. Radio protocols and transcripts from space missions (Gemini to Skylab) let us understand space food from the astronaut's point of view. Because of the volume of the 386 transcripts from 1961 to 1974 and their conversational character, the research style Grounded Theory was determined as the preferred analyzing procedure (Glaser and Strauss, 1967). Codes and personal memos were created throughout the research process and repeatedly updated and improved according to the principles of Grounded Theory with a special focus on continuous comparison. The qualitative data analyzing tool MAXQDA was used for analyzing, coding and memoing the radio protocols and transcripts (Kuckartz and Rädiker, 2019; Given, 2008).

Nutrition and Compliance: The Researcher's Perspective

With the advent of Nutrition as a discipline in the 19th and early 20th century the constituents of food and its metabolic properties came under scrutiny (8). However, for NASA's Food and Nutrition Branch (F&N) the understanding of nutrition and physiology was far from complete. The F&N nutritionists conceptualized food as part of the life support system of the spacecraft environment. To fulfill its life support function, food had to work with the same safety, precision, and measure of control as any other part of the spacecraft. The 1974 Apollo Food System Experience Report stated accordingly: 'Manned space flight requires accurate control of the environments in spacecraft to maintain life. Food is an indispensable part of that environment.' (NASA TN D-7720, p.9). Food itself became a technological system but also an experimental system to generate new knowledge (Rheinberger, 2006, pp.25–27). To achieve the necessary precision and safety of the spacecraft's food system, NASA's nutritionists had to ascertain what elements food consisted of and what effects it had on the metabolism of the astronauts (Spiekermann, 2018, pp.631–641).

How F&N turned these aims into research programs is particularly interesting in the case of Skylab, the first United States space station. Several experiments on this space station were concerned with the mineral and metabolic balance of the astronauts (NASA SP-377, Sec. III-V). This meant exact control not only of food intake, but also of fecal and urinary output. As a letter from 1975 boasted, it was possible for 94 different Skylab foods that '… each serving portion was controlled within a tolerance of ±2% for a content of 7 critical nutrients (Calcium, Phosphorus, Potassium, Magnesium, Sodium, Nitrogen, and energy)' (9). Urinary and fecal samples were stored on board, brought home, and then analyzed in complex research schemes (10). On earth, bed-rest studies were used to analyze the symptoms of bone density loss (11). The knowledge to be obtained was closely linked to the methods of its obtainment. How nutrients circulated in the astronaut's body could only be understood by letting them circulate and observing the circulation closely, thus creating what space historian Jordan Bimm (2018, p.170) recently called the astronaut's 'data body'. Paul C. Rambaut, the principal coordinating scientist for the metabolic balance study (MO71), laid out the in-flight measurement regimen accordingly: 'As a metabolic balance study, MO71 will be considered successful if accurate data are obtained on the mass and chemical composition of all material entering and leaving the body, by any major route, throughout the preflight, inflight and postflight phases of the AAP missions' (12). Thus, not only the spaceship as an artificial environment was conceptualized as a system of closed loops of circulation, but also the astronaut's body. Mediating and shifting between these two systems of circulation were space food and fecal matter, whose connections and linkages NASA visualized in ever more complex diagrams (13).

The astronaut occupied the critical node both of the loops of circulation and the experimental designs. Not only was his metabolism to be investigated but the data accumulation and strict adherence to research protocols rested squarely on his shoulders too. Once in orbit, F&N scientists were reduced to mere bystanders in their research and were solely reliant on astronautic compliance. This, however, was not a given, and the researchers therefore tried to implement mechanisms to reduce the appeal of deviance. Beginning with early drafts, NASA's researchers determined that Skylab astronauts should be motivated to eat food packages completely to make their research easier:

> Despite the admirable and essential food system change to homogeneity of each food so that each food left-over would be identical in composition to that of the original whole package, accuracy would be significantly aided by actual return (for analysis) of all food left-overs. Investigators would then not be totally dependent on the astronaut's weighing and recording. For engineering calculations relative to weight, etc., estimate 5% to be top limit of left-overs. Incentive to the astronauts to complete ingestion would be the need to weigh, record and store any left-overs (14).

Engineers developed a Specimen Mass Measurement Device (SMMD) to weigh food leftovers in case the astronauts did not finish their meals, but also to weigh urine bags, faeces and vomitus to keep track of any input and output (15). An accompanying Body Mass Measurement Device (BMMD) on the other hand functioned as a zero-g scales for the astronauts (16). While the BMMD worked well for the Astronauts – and there was no way around using it – they avoided the SMMD as it was a complicated machine (Kerwin and Seddon, 2002, p.923). Fecal and Urine samples had to be measured anyway but the easiest strategy to avoid measuring food leftovers was to finish each plate just like the scientists had speculated in the initial planning phase (17).

Another strategy of NASA's scientists was to appeal to a military sense of duty that they hoped would still be present in the former fighter pilots (Levi, 2007; 2010; McCurdy, 2007)(18). J.W. Humphreys, NASA Director of Space Medicine, reprimanded the astronauts during a 1969 conference on space food (NASA SP-202, p.4):

> One item which has not been widely mentioned is that in our system the food discipline of the crewmembers has been poor. I have said this to them, so I will say it in public: Food and water discipline is something that soldiers learn early or they do not survive. The space crews have not been very disciplined about their eating – they have picked, traded, and done as they pleased. That is permissible if no scientific metabolic information is to be obtained but food discipline must be enforced in flight if we are to determine whether a system is good and how it should be changed. It is particularly important in those flights in which we have experimental protocols that must be complied with.

Living and Eating in Space: The Astronaut's Perspective

The original planning for Skylab, proposed that every astronaut should receive the exact same amount of calories and nutrients each day to better observe differences in metabolic behavior, not just between earth and space but between different crew members as well (19). But the astronauts and their Director Deke Slayton resisted these efforts and questioned the competence of the principal investigators (PI's):

> Flying in the face of 10 years manned space flight experience, some Skylab PI's are driving Skylab food protocol and menus to the brink of crew unacceptability. This Directorate believes in and supports legitimate requirements for procurement of medical data. However, we also know that unless food is palatable and in proper quantities the crews will not eat it, which not only blows a number of medical experiments, but potentially the whole mission. [...] We are not raising goose livers and it is unreasonable and unrealistic to expect to force feed astronauts (20).

After several heated exchanges the idea was finally shelved (Kerwin and Seddon, 2002, p.922). At least, one Skylab astronaut, Joseph P. Kerwin (2000), thought of himself not just as a lab rat or a goose liver: 'We weren't just guinea pigs; we were also co-investigators, informally, on all the experimental work that went on. Had a wonderful time doing it.' Before Skylab, during Apollo 16 John Young famously complained about potassium fortified orange juice. After Apollo 15, the medical staff had noticed post-flight cardiac arrhythmia and suspected a potassium deficiency to be the reason. Potassium fortified orange juice was flown on Apollo 16 to test the hypothesis and ground control urged the crew to drink as much as possible (NASA TM X-58096). John Young however blamed the excess of fortified orange juice for a sour stomach and flatulence. Not noticing that the radio link to the ground station was still live he complained to his crew mates:

> *Young:* I mean, I haven't eaten this much citrus fruit in 20 years! And I'll tell you one thing, in another 12 fucking days, I ain't never eating any more. And if they offer to sup me potassium with my breakfast, I'm going to throw up! I like an occasional orange. Really do. But I'll be darned if I'm going to be buried in oranges (21).

Generally, the astronauts of all missions saw themselves as co-investigators in the overall research project of making space habitable for man. But in contrast to the earth-bound scientists, they already inhabited spaceships and space stations. For the astronauts, making space habitable was not just a research task, it was a lived experience. So, while the F&N scientists were concerned with the experimental and scientific side of food, the astronauts saw food consumption also as a basic everyday necessity and used food as the cornerstone for their recreational activities and conversations in space. Perfectly working daily routines were essential for the mission. Misplaced items or time-consuming food preparation and storage procedures that were a result of research protocols, interfered with the more essential technical and scientific duties (22). Nevertheless, the astronauts tried their best to follow the nutritionists plans and recommendations but were not always able to do so. If malfunctions or problems with food packages occurred, the astronauts reported them to ground control and the astronauts sometimes took an almost personal interest in the precise engineering of food packages and their further development for upcoming missions:

> *SPT:* As far as the food is concerned, some of the cans don't fit the size of the slots. There'd ought to be better control on the position. I had to put napkins around some of my small cans to make them fit into the slots so that they don't all float out and get lost. They should have been done better... (23)

Food and food related topics also played a significant role in the astronaut's leisure activities and social interactions. Besides talking about mission objectives and upcoming tasks, the mission transcripts show that food – and eating food – was a main topic in the astronaut's daily conversations. It must be kept in mind though, that the astronauts never talked privately. The public followed every interaction with ground control, and NASA had handed the astronaut's guidelines concerning what to talk about and how (Haney, 2003). Internal conversations amongst themselves in the spacecraft were monitored, transcribed and evaluated by NASA personnel that listened in to decide future flight assignments. So self-censorship was probably a common practice for the seasoned former military pilots (Wolfe, 2005, pp.30, 94–95; Bimm, 2014, pp.43–44; Hersch, 2013). There were not many harmless topics to discuss in space and food was one of them. During Apollo 9 and 16, as well as in Skylab 2 and 4, the main food theme the astronauts talked about was food preparation and taste. Eating was not only one of the few leisure and recreational activities but also one of the few pleasureful ones – at least when the food tasted good. If it didn't, the astronauts employed different strategies. For example, Apollo Astronauts on the one hand started to trade food according to their appetites in a playful barter, while Skylab 4 Pilot, William R. Pogue, on the other hand complained to ground control about the lack of morale boosting comfort food:

> *PLT:* In terms of you zero-g living – Oh, another thing for recreation. I think we definitely ought to have something to eat of a pleasure nature. This food experiment we got on this thing is – I think, is highly detrimental to morale as far as the recreation and feeling good sort of thing, in the sense that it does not provide what I call pleasure food (24).

The effects of space food on digestive functions is a remarkably often picked-up conversation topic of the astronauts throughout all missions. The cramped quarters made privacy impossible. Faulty fecal and urinary bags caused constant embarrassments while complaints about flatulence inducing foods were common during most crewed spaceflights:

> PLT: We generate so much flatus, we have to pass so much gas, that you're laundry marking your shorts all the time. And that, I think, probably sounds a bit flippant, but I think it's an – it is a problem. And I don't want to pass over the flatus problem lightly because I think passing gas about 500 times a day is not a good way to go.

> PLT: What is the most disconcerting personal hygiene problem you have encountered? I think I just mentioned it – Passing gas about every 5 minutes. And I don't mean just a nice little pooh; I mean really passing a big blast of gas (laughter). It's just not a nice thing. It – it offends people around you, and the only redeeming feature is that everybody else is passing the same amount of gas. It's a good thing we got some charcoal canisters taking the stuff out (25).

As time went by there were linguistic changes in the astronaut's conversations from Gemini in the 1960s to Skylab in the 1970s. The astronauts got 'looser' in terms of their choice of language and food talk became more colorful. This could be interpreted as a loosening of regulations by NASA, or more lax self-censorship by the astronauts themselves. But space exploration itself got 'looser' as NASA's manned space program moved further away from its military origins (26). Space technology matured and life in space became more and more 'normal'. Therefore, daily routines got comparable with life on earth and personal demands towards taste and food package usability increased (Cubasch, 2019). While Apollo missions were regarded as 'camping trips' into space with minimal comfort, the culinary expectations of the astronauts rose in proportion to their time in orbit (Levi, 2009, p.107; 2010, p.11). Skylab Astronauts therefore not only dined at a table but also desired their food to come close to earth bound fare:

> *SPT:* Most of the wet – wetpacks – I suppose they are satisfactory by Apollo standards, but they're not very satisfactory by Earth-based or even Skylab standards. ... And so I don't think those wetpacks are a satisfactory design for food containers (27).

Habitability first: The Engineer's Perspective

Astronauts didn't just quarrel with F&N scientists and vice versa. As an engineering agency, NASA usually gave preference to technical considerations, while scientific interests took second place (Burrows, 1999). Conflicts between the differing value systems and interests of science and engineering departments that work closely together in complex projects are to be expected in technoscientific environments like NASA (Geppert, 2012, p.220; Rheinberger, 2006, pp.31–32). The Apollo Food System Experience Report (NASA TN D-7720, p.1) only hints at such conflicts between engineers, scientists and a further group of 'interested non-consumers (the program, system, and subsystem managers)'. The internal conflicts during the development of the Skylab Food System however were so severe that they found their way into NASA's own historiography (Compton and Benson, 1983, Ch.7). The management and distribution of tasks between competing working groups at the Manned Space Center in Houston and the Marshall Space Flight Center in Huntsville, Alabama lead to tensions between engineers, nutritionists, and subcontractors (28). Paul C. Rambaut, the aforementioned principal coordinating scientist for the MO71 metabolic balance study, on one occasion deemed these tensions 'personally insufferable' and threatened to resign at the beginning of 1969 (29). The conflicts mostly stemmed from differing perspectives on food that contested the nutritional interpretation of food by the F&N scientists. One of the bigger project goals of Skylab was to make the space station as habitable and comfortable as possible. In charge of this habitability project at the MSC was Caldwell C. Johnson, Chief of the Spacecraft Design Office (SDO). For him habitability came first. A design of the food system centered on nutritional research stood in the way of achieving habitability and was difficult to accommodate into Skylab's technical envelope. Malcolm S. Smith, Chief of F&N was taken aback by Johnson's approach:

> Mr. Johnson pointed out that the food system was troubled by conflicting requirements and was poorly integrated into the OWS engineering system. He reiterated his thesis that no nutritional or physiological problems existed and that the solutions were purely engineering. I should have pointed out that time that his qualifications to judge the nature and extent of physiological problems are questionable (30).

From then on, a conflict between the Food & Nutrition Branch and the Spacecraft Design Office ensued that lasted well into the Shuttle era (31). F&N personnel wanted to design the food system by defining the nutritional composition of food items first, continuing with the composition of meals, while technical integration and packaging of the food was supposed to happen in the final stages of development. Johnsons' SDO on the other hand started with developing new food packages, drink dispensers and heating trays (32). It were not only different development strategies that created friction but also the differences in style of research. The F&N nutritionists moved carefully and favored a step by step approach inside the broader academic community of nutrition research. Johnson in contrast seems to have favored a more creative hands-on approach to food in his workshop to the bewilderment of F&N Chief Smith who did not see creativity but waste when he complained about Johnson's: '[...] continual subtle creation of problems and subsequent dramatic solutions' (33). The conflict reached higher administrational levels, when SDO started to award its own food research subcontract to the aerospace company Fairchild Hiller without consulting Food & Nutrition. By doing so, SDO trespassed into F&N's core responsibility of allocating food research resources and Charles M. Berry, the medical research director at the MSC intervened on behalf of F&N in a memo to the director of engineering, Maxime A. Faget, who was the Johnson's superior. Calling Johnson's behavior 'unprofessional and insulting' he demanded an immediate cancellation of ongoing food research at the engineering department. He felt that not only the direction of the research contract with Fairchild Hiller was misguided as it centered heavily on engineering instead of nutrition, but that Johnson '[...] has done a severe disservice to himself and to the Manned Spacecraft Center through his arrogant disregard of the professional advice of the food and nutrition staff at this Center on the subject of food systems development' (34).

Not Just Whipped Up: Redesigning Cultural Techniques of Cooking

At the same time, the F&N Branch seems to have grappled with its own role between being a basic research division that focused on nutrition and physiology and being a mission support division whose main task was to engineer and manufacture foods for space flights (35). NASA's F&N not only tried to study and control the composition and metabolism of food but also the cultural techniques of cooking and eating as well. Food related cultural techniques like food preparation, eating, and disposal were at the very heart of making space habitable. To observe these informal practices and in order to explicate their implicit knowledge, F&N employed media arrays – like films, photographs, taste panels, taste review sheets, and food consumption trainings – that were only partially based on written knowledge documentation and transfer. Researching the ideal preparation techniques for the Skylab food system for example, was of equal interest as controlling its composition. Skylab foods were to be reheated with a heating tray. But to develop a heating tray, F&N first had to know how foods got hot, especially when the zero-g environment in space prohibited convection flows. Therefore, F&N tried to devise a study of zero-g food heating on earth but ran into difficulties while simulating space cooking:

> My current ideas for changes involve setting up conditions which best resemble those in a space environment, e.g., simulating the absence of

> convection by heating in vacuum. This poses one immediate problem since foods containing water simply undergo freeze dehydration as they are heated from the frozen state in vacuum. The next approach would be the use of model systems for the food such as cork, plastic or wood blocks to minimize vaporization under vacuum. This unfortunately, will result in a study of the heating of cork, plastic and wood block under vacuum and not necessarily the heating of food in a spacecraft environment. Perhaps, therefore, this study could best be directed towards the determination of some fundamental data upon which we could base our future calculations – such data as thermoconductivity, and specific heats of foods and heating of foods with different moisture contents, etc. (36)

This interest in food properties beyond nutritional content and the exact workings of cultural techniques like heating food were not just purely academic. The engineers of Skylab's energy subsystem needed to know precisely how much energy the food system would consume to specify their system accordingly (Compton and Benson, 1983, Chap.7). The next logical step was therefore to subject the cultural techniques of food preparation (and consumption) to a redesign process that optimized them for space application. On the basis of its newly gathered explicit knowledge, F&N tried to improve food by means of engineering. The first cultural technique to be replaced was cooking, as Apollo Food System Manager Rita Rapp told the *Colorado Springs Sun* in 1971:

> The food we sent with the Apollo XV astronauts into outer space is not just whipped up – it's engineered. If an astronaut requests a certain kind of cookie, then we construct it, according to carbohydrates, fats and proteins (37).

Of course, the traditional medium that supported the cultural technique of cooking – recipes – was discarded as well. Space food engineering required new methods of documentation: Food specifications that NASA personnel developed in an iterative process of trial, error, and reformulation of specifications (LaChance, 2006). One main goal of this cooking by specification was to reduce possible microbiological contamination of the foods to a minimum by identifying critical control points where a contamination might occur along the manufacturing steps, and monitoring them closely (Ross-Nazzal, 2007). In the words of NASA's first F&N Branch chief, Paul LaChance (2006):

> So your spec would say that you want a minimal amount of that or that you want it—in this case, we would be going through a shredding process, a cooking process, a pressure-canning process, the actual—then these items were freeze-dried when they were done, so you add another step. The processing step included cooking it so that it's ready to eat. Then you check your end item.
>
> The challenges otherwise were learning, were how to spec the food in the first place, the ingredients that you were going to put together. I mean, you know, you could spec a beef stew, for example, and use a certain spice, and that one spice could ruin the whole thing if it wasn't sterile or close to it [...].

The new media to record the specifications were the 'Manufacturing Requirements of Food for Aerospace Feeding', which laid out the steps a private contractor had to follow to manufacture flight worthy foods. To properly produce 'Bacon Squares Compressed', the producer would have had to follow six pages of instruction, that specified width, length, thickness, weight, moisture to salt ratio, microbiological limits, and of course the prescribed pressure to be applied to the bacon (38). The other medium was a series of detailed flowcharts that showed the succession of production steps and their respective critical control points. Together with 'In-Process Inspection Procedures' and a 'Check-Off Sheet' these flowcharts helped to document any possible failure or contamination while – in terms of cultural techniques – transforming mundane acts of cooking into aerospace compatible acts of manufacturing with zero contingencies (39). F&N's nutritionists also welcomed newly devised foods from industry partners or other research agencies. In 1968, the United States Department of Agriculture proposed a way to integrate fruits into space food systems: They had developed orange juice pills that 'appear to be a natural for space food in view of their compactness, palatability, and high concentration of nutrients.' The product description that has survived in the records from F&N describes the production as follows:

> In the 'foam-mat' process, a liquid food such as frozen orange concentrate is mixed with a foaming agent, whipped into a thick foam, and the moisture is removed by passing hot air over and through it while it is spread out in a thin sheet. [...] The instant orange juice produced in this manner, however, had a very large volume for a given weight. In studying ways to increase powder density and thereby improve solubility, the idea was developed of compressing the citrus solids into tablet form for eating like candy. These tablets consist of about 99% natural citrus solids and contain all of the normal nutritive advantages of natural citrus juices including Vitamin C, caloric content, and other vitamins and minerals (40).

All this preparation effort aimed at making food consumption as easy as possible for the astronauts and followed the general trend in the 20th century of shifting food preparation away from the end consumer to earlier points in the production chain (Fischler, 2013). Not only was the astronaut's body supposed to be a weak link in the harsh conditions of space exploration but also the astronaut's ability to cook. Therefore, everything had to be simple, as one of the nutritionists laid out during the preparation of the Apollo mobile quarantine facility (MQF):

> Heating in the microwave oven should be the only procedure required in meal preparation. [...] No assumption of any kind must be made regarding the culinary aptitudes of the incumbents of the MQF. They must be asked only to open the food packages and heat items that need heating for the time clearly specified on the package. No elaborate instructions should accompany the food packages or be necessary (41).

Sugar Tongs and Titration Tools: Redesigning Cultural Techniques of Eating

After cooking, of course, comes eating. Cultural techniques of eating are again heavily mediated practices. What is eaten, and when, where and how, is deeply linked to the artifacts in use, e.g knives, forks, chopsticks or 'titration tools' and 'sugar tongs'. These at least were the methods envisioned by Wernher von Braun and Walt Disney in their TV-programme, *Man in Space* (1955). 'Dining under conditions of weightlessness', space physician Heinz Haber tells the audience, 'will present new and surprising problems'. Drinks, he argues, would have to be handled with baby bottles, and titration tools, while microwaved foods would have to be eaten with sugar tongs as part of 'space etiquette'. At least in this vision there was still a proper Martini to be had and delicious food. The reality looked somewhat different. Food during the days of Gemini and early Apollo came in plastic pouches that had to be opened with specially designed scissors, as two preserved films from F&N and one of its subcontractors, Whirlpool Corp., demonstrate (42). Rehydratable foods were especially complex to handle. After cutting the valve latch, a water gun had to be inserted. Then, after rehydration, extensive kneading followed. During the next step the astronaut cut open the other side of the plastic pouch and sucked the food out of it. Finally, a germicide tablet had to be cut loose from another pouch and then transferred to the mouthpiece and squeezed from there into the primary food pouch. The Apollo food system and Skylab food system used additional food packaging technologies, as for example the Apollo spoon bowl pack, and the Skylab beverage containers that were handled like an accordion.

Even these demonstrations in front of a camera on earth did not progress without spillage and sticky fingers. In a cramped spacecraft, under conditions of weightlessness, handling these food pouches became an ordeal, as voice transcripts and radio protocols from as late as Skylab 3 corroborate:

> *CDR:* Hello. This is for food people. Malcom Smith would be a likely candidate, along with Rita. We got a friendly Rice Krispies this Morning, and I filled them up with water. And it's one of those spoon bowl packs, and the seal never seems to take place in the area where it should. So when you mix up your Rice Krispies, instead of having – being able to cut along the black line, you have to cut right near the top, because the Rice Krispies is moved up past the bast – bacle – black line. Now that's not new-news because apparently it happened a lot on the previous mission, but I thought I'd let you know we seem to continue to have the problem here (43).

Contractors like Whirlpool Corp., which was one of NASA's main contractors for space food during Gemini, Apollo, and Skylab were partly at fault. Whirlpool itself had subcontracted the production of food pouches and overwraps to other companies and 'integrated' the products for shipment (44). The immature sealing techniques for the food pouches posed the main problem together with the diverging properties of the different materials like aluminum, nylon, and polyethylene that were laminated together for food pouches and overwraps. The records of F&N hold several complaints about mislabeled shipments and non-vacuumed or porous plastic pouches that came from Whirlpool, and the reject rate reached as much as 10 to 15 percent during Gemini and Apollo (45). However, even a meticulous quality control could not prevent faulty packages from travelling to space and their complex design and handling procedures did not help either. Technical problems with food pouches or food spillage came up often in zero-g conversations during Apollo 9 and 16, as well as Skylab 3 and 4, where spoons were designed too short:

> *PLT:* ... Also, you can't eat out of them with the short spoon that we've got without getting your fingers all messy because the spoon is about as long as the pack is... (46)

The Crew of Gemini 7, Frank F. Borman and James A. Lovell, transmitted a flurry of angry messages down to ground control and the then F&N chief Paul LaChance, about crumbs, defective food pouches, clogged mouthpieces, and water valves. Their disapproval culminated in Borman's angry remark at 160:14:32 'Another note for Dr. Chance: I agree it looks like we're in a snowstorm with crumbs from the beef sandwiches. At 300 dollars a meal! I think you can do better than this' (47).

Conclusion: Future Foods in Technoscientific Environments

As Mackert (2014, p.222) has shown, food and eating are important territories of foucauldian 'subjectification' – positioning oneself as a successful individual in society's fabric of rules and norms. That holds true not only for society as a whole but also for occupationally differentiated subgroups like nutritionists, food system engineers, and astronauts. For all three groups of actors their occupation and their role in space exploration determined their perspective on space food. Respectively their particular perspective of what space food was supposed to be, embedded them in their occupational group. These different groups inside NASA however were not able to permanently establish their own interpretation of food as the predominant definition. Nutritionists thought of food in terms of nutrients and demanded exact control and adherence to research protocols, while astronauts asked themselves whether they were part of the experiment or experimenters themselves. Food system engineers on the other hand tried to make foods flight worthy and space habitable by overhauling and explicating traditional cultural techniques of cooking and eating. Cooking and eating thus became engineering processes that accorded to previously set specifications.

But aiming for new technologies of 'eating without effort' – Oddy's (2003, p.302) hallmark of fast food – NASA's F&N personnel did not always hit the mark, with what could be described as a tendency towards over-engineering and disrupting cultural techniques of food at all costs (Bourland and Voigt, 2010, pp.22–23). Literal ruptures of faulty plastic pouches sent food sailing through spacecrafts and astronauts chasing and cursing. Handling these new space foods proved to be a time-consuming and messy affair that hampered astronauts trying to complete their busy schedules in space. Having to follow extensive food-related research protocols did not help and astronaut's complaints to ground control are well documented. On the other hand, food was one of the few leisure activities in early spaceflight and one of the safest to talk about in cramped quarters under constant surveillance. It gave a sense of normality and camaraderie to the situation. As Director of Space Medicine Humphreys correctly observed (NASA SP-202, p.4), the astronauts 'have picked, traded, and done as they pleased.' For the astronauts, food was not just a research object and human necessity to fulfill ones more important duties: it was also tasty. Or at least it was supposed to be.

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Notes

1. 'Letter from Charles Berry, Director of Medical Research and Operations to D.M. Hegsted, Professor of Nutrition, Harvard University', Mar. 14, 1969, Box 1 – Correspondence February 1967 – April 1970, Folder 03 – January-March 1969, Food Systems (R.Rapp's Files), Center Series. JSC History Collection, University of Houston: Clear Lake Archives.
2. NASA Meal System for the Elderly Exhibit at the Health Museum, Mar. 10, 1977, NARA ID: 17451434, NARA at College Park – Still Pictures. See Belasco (2006, pp.230–235) and Tanner (2014) for similar approaches with Algae.
3. See for more examples: Flentge, Robert L. and Bustead, Ronald L., SAM-TR-70–23, 'Manufacturing Requirements of Food for Aerospace Feeding.', Box 8 – General Food and Nutrition Materials (Non-program Specific) 1968–1970, Folder May 1970, Food Systems (R.Rapp's Files), Center Series. JSC History Collection, University of Houston: Clear Lake Archives.
4. Apollo 8, Onboard Voice Transcription, January, 1969, Day 3, 02084206, Page 65.
5. Apollo 7, Onboard Voice Transcription, December, 1968, Day 6, 05222208, Page 224.
6. Gemini 7, Air-To-Ground, Ground-To-Air, Onboard, March, 1988, 149:45:35, Page 458; Apollo 12, Technical Air-To-Ground Transcription, November, 1969, 02092456, Page 169.
7. For NASA's struggle with race, class, gender and diversity in the 1970s see (McQuaid, 2007).
8. See Boyd (2001, p.636), Carpenter (2003a; 2003b; 2003c; 2003), Neswald, Smith, and Thoms (2017), Kassung (2020), Tanner (2014, pp.344–345), and Spiekermann (2006).
9. 'Letter from Malcolm S. Smith to the American Veterinary Medical Association', Jan 29, 1975, Box 5 – Correspondence November 1972 – 1975, Folder Correspondence 1975, Food Systems (R.Rapp's Files), Center Series. JSC History Collection, University of Houston: Clear Lake Archives.
10. 'Fecal Analysis Flow Chart', 1973, Box 20, Folder MSC-07705, 'Food and Nutrition Skylab Support Program' Jan 29, 1973, Food Systems (R.Rapp's Files), Center Series. JSC History Collection, University of Houston: Clear Lake Archives.
11. 'Experiment MO78 – Bone Mineral Measurement', Jan. 8, 1975, Box 5 – Correspondence November 1972 – 1975, Folder Correspondence 1975, Food Systems (R.Rapp's Files), Center Series. JSC History Collection, University of Houston: Clear Lake Archives.

12. 'Inflight medical requirements imposed by MO71', Oct. 16, 1968, Box 1 – Correspondence February 1967 – April 1970, Folder 02 – October-December 1968, Food Systems (R.Rapp's Files), Center Series. JSC History Collection, University of Houston: Clear Lake Archives.
13. For one of Skylabs military predecessors see 'Whirlpool Corp. Systems Analysis for MOL Feeding System', 1969, Box 19 – MOL / Skylab 1969–1972, Folder – Whirlpool Corp. Systems Analysis for MOL Feeding System, Food Systems (R.Rapp's Files), Center Series. JSC History Collection, University of Houston: Clear Lake Archives. For even more radical concepts of integrating man and spaceship trough waste collection and algae consumption during the Skylab planning phase, see Munns & Nickelsen (2017).
14. 'Planning Conference on AAP Metabolic Studies, MSC. Houston, Feb. 10, 1969', Feb. 17, 1969, Box 1 – Correspondence February 1967 – April 1970, Folder 03 – January-March 1969, Food Systems (R.Rapp's Files), Center Series. JSC History Collection, University of Houston: Clear Lake Archives.
15. 'Food Specifications for Skylab', May 26 1970, Box 2 – Correspondence May 1970–January 1971, Folder 01 – May 1970, Food Systems (R.Rapp's Files), Center Series. JSC History Collection, University of Houston: Clear Lake Archives.
16. 'Specimen Mass Measurement Device (SMMD) and Body Mass Measurement Device', May 5 1970, Box 2 – Correspondence May 1970–January 1971, Folder 01 – May 1970, Food Systems (R.Rapp's Files), Center Series. JSC History Collection, University of Houston: Clear Lake Archives.
17. Skylab 3, Onboard Voice Transcription, October, 1973, 212005120, Page 162.
18. For the military origins of the astronaut's subject formation see for example Bimm and Kilian (2017) and Bimm (2018).
19. 'Memorandum from CA/Director of Flight Crew Operations Deke Slayton to DA/Director of medical Research and Operations and KA/Manager of Flight Crew Operations', June 4, 1971, HSI-143436, University of Houston: Clear Lake Archives.
20. 'Memorandum from CA/Director of Flight Crew Operations Deke Slayton to KA/Manager of Flight Crew Operations', March 1, 1971, HIS-143429, University of Houston: Clear Lake Archives.
21. Apollo 16, Mission Commentary, April, 1972, CST 21:32, Page 494/2.
22. Skylab 1/4, Onboard Voice Transcription, March, 1974, 331212313, Page 494., Skylab 1/2, Onboard Voice Transcription, July, 1973. Day 145, 153518, Page 18.
23. Skylab 3, Onboard Voice Transcription, October, 1973, 222020828, Page 628.
24. Skylab 4, Onboard Voice Transcription, March, 1974, 365214853, Page 2028.
25. Skylab 4, Onboard Voice Transcription, March, 1974, 347152324, Page 1034.
26. See Maher (2017, pp.183–228) for a discussion of NASA's 'squareness' and Burrows (1999, p.443) for NASA's shifting priorities after Apollo 11.
27. Skylab 3, Onboard Voice Transcription, October, 1973, 222020828, Page 628.
28. 'Memorandum from DB3/Chief Food and Nutrition Malcolm S. Smith to DA/Director of Life Sciences', Feb 11, 1974, Box 5 – Correspondence November 1972 – 1975, Folder January – June 1974, Food Systems (R. Rapp's Files), Center Series. JSC History Collection, University of Houston: Clear Lake Archives.
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Feb. 11, 1974, Box 5 – Correspondence November 1972 – 1975, Folder January – June 1974, Food Systems (R.Rapp's Files), Center Series. JSC History Collection, University of Houston: Clear Lake Archives. See also LaChance (2006).
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37. 'Dolly Hlava, Apollo 15 Space Food–A Taste of Home, Colorado Springs Sun, Page 7', Sept. 22, 1971, Box 8 – General Food and Nutrition Materials (Non-program Specific) 1968–1970, Folder – Rita Rapp – Newspaper Articles 1968–81, n.d., Food Systems (R. Rapp's Files), Center Series. JSC History Collection, University of Houston: Clear Lake Archives.
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43. Skylab 3, Onboard Voice Transcription, October, 1973, 217114601, Page 238.
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46. Skylab 3, Onboard Voice Transcription, October, 1973, 222020928, Page 621.
47. Gemini 7, Air-To-Ground, Ground-To-Air and On-Board Transcription, March, 1988, 160:14:32, Page 461.

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